ADAPTIVE ANTENNA

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to an adaptive antenna for use with a base station for a mobile communication system, a local area radio communication system, and so forth.

2. Description of the Related Art

As an antenna for use with a base station for a mobile communication system, an antenna that form a plurality of sector beams is used. In the antenna, an area of 360 degrees on a horizontal plane of the base station is covered with a plurality of beams. As an example, six beams with a beam width of 60 degrees are disposed in the circumferential direction. As an antenna that forms sector beams, a dipole antenna with reflector is known. In this antenna, the beam width depends on the size of the reflector and the height of the dipole to the reflector.

However, such an antenna that form a plurality of beams does not have a means for controlling the difference of communication amounts of beams in the service area that the base station covers. For example, in an area of a particular sector beam, the communication amount is very large. In an area of another sector beam, the communication amount is very small. Such a situation often takes place. When the communication amounts are unbalanced among beams on the time base, such a problem can be solved by initially changing the beam widths of sector beams or initially changing the number of channels that are accommodated in the individual sectors. But in the case that unbalanced communication traffic may often change, it is difficult to overcome such a problem by using the conventional antenna.

SUMMARY OF THE INVENTION

An object of the present invention is to provide an adaptive antenna that allows patterns of a plurality of beams that cover a predetermined service area to be flexibly varied corresponding to communication environments.

Another object of the present invention is to provide an adaptive antenna that allows the communication amount to be well-balanced among beams and the communication capacity of the base station to be effectively used.

A further object of the present invention is to provide an adaptive antenna that allows the patterns of beams to be stably and optimally to be controlled so as to well-balance the communication amounts among beams.

To accomplish the above described objects, the present invention is an adaptive antenna, comprising a plurality of antenna elements for forming a plurality of beams that cover a predetermined service area, a detecting means for detecting the communication amount of data transmitted or received with each of the beams, and a controlling means for controlling a pattern of each of the beams corresponding to the detected communication amount.

In the adaptive antenna of the present invention, the controlling means has a beam pattern controlling means for controlling a pattern of each of the beams corresponding to the detected communication amount so as to cause the communication amounts of the beams to be nearly matched.

Thus, according to the present invention, patterns of a plurality of beams that cover a predetermined service area can be flexibly varied corresponding to variations of communication environments. Consequently, the communication amounts of beams can be prevented from deviating. As a result, the communication capacity of the base station can be effectively used. Thus, the number of terminals that can be accommodated can be increased. The adaptive antenna of the present invention has a plurality of first antenna elements and a plurality of second antenna elements, the first antenna elements composing a transmitting antenna portion, the second antenna elements comprising a receiving antenna portion and being analogous to the transmitting antenna portion, the ratio of the size of the transmitting antenna portion to the size of the receiving antenna portion being equal to the reciprocal of the ratio of a transmission frequency to a reception frequency. Thus, the shapes of the transmitting sector beams are always the same as the shapes of the receiving sector beams. Consequently, a communication defect due to the difference of shapes of sector beams can be prevented. Thus, good communication environments can be always maintained.

In the adaptive antenna of the present invention, the controlling means has a means for controlling a pattern of each of the beams when the maximum communication amount of each of the beams exceeds a predetermined value. Thus, according to the present invention, only when the communication amount of a particular beam becomes excessive, the patterns of individual beams are controlled so as to well-balance the communication amounts among the beams. Consequently, since an unnecessary controlling process is omitted, the adaptive antenna can be stably controlled.

In the adaptive antenna of the present invention, the beam pattern controlling means controls the beam widths of at least a first beam and a second beam, the first beam having the maximum communication amount, the second beam having the minimum communication amount. In this case, the beam pattern controlling means controls the beam widths of at least a first beam and a second beam, the first beam having the maximum communication amount, the second beam having the minimum communication amount while keeping the sum of the beam width of each beam nearly constant. Thus, even if the patterns of beams are varied, an area that is not covered can be prevented from taking place.

These and other objects, features and advantages of the present invention will become more apparent in light of the following detailed description of a best mode embodiment thereof, as illustrated in the accompanying drawings.

BRIEF DESCRIPTION OF DRAWINGS

FIG. 1 is a block diagram showing the structure of an adaptive antenna according to an embodiment of the present invention;

FIG. 2 is a schematic diagram showing the structure of a weight setting portion and an amplifying portion for a receiving antenna portion of the adaptive antenna shown in FIG. 1;

FIG. 3 is a top view showing the adaptive antenna according to the embodiment of the present invention;

FIG. 4 is an external view showing the adaptive antenna shown in FIG. 3;

FIG. 5 is a flow chart showing a process of an antenna controlling portion of the adaptive antenna shown in FIG. 1;

FIG. 6 is a schematic diagram showing beam patterns in the case that the beam widths of individual sector beams are 60 degrees in the adaptive antenna according to the embodiment of the present invention;

FIG. 7 is a schematic diagram showing a first example of which the beam patterns shown in FIG. 6 have been varied;

FIG. 8 is a schematic diagram showing a second example of which the beam patterns shown in FIG. 6 have been varied; and

FIG. 9 is a schematic diagram showing a third example of which the beam patterns shown in FIG. 6 have been varied.

DESCRIPTION OF PREFERRED EMBODIMENTS

Next, with reference to the accompanying drawings, embodiments of the present invention will be described.

FIG. 1 is a block diagram showing the structure of an adaptive antenna according to the embodiment of the present invention.

The adaptive antenna according to the embodiment of the present invention is an antenna for use with a base station. The adaptive antenna covers an area of 360 degrees on a horizontal plane of the base station with six sector beams.

Referring to FIG. 1, the adaptive antenna has a receiving antenna portion **1** and a transmitting antenna portion **2**. The receiving antenna portion **1** and the transmitting antenna portion **2** each form six sector beams with a 12-element array. The sizes of the receiving antenna portion **1** and the transmitting antenna portion **2** and the intervals of the antenna elements depend on the frequency bands (or wave lengths) of radio waves that are received and transmitted. In reality, the receiving antenna portion **1** and the transmitting antenna portion **2** have different sizes and are analogous to each other. The shape parameter of the transmitting antenna portion **2** is equal to [reception frequency/transmission frequency] times the shape parameter of the receiving antenna portion **1**. For example, assuming that the transmission frequency is 1 GHz and the reception frequency is 2 GHz, the size of the transmitting antenna portion is twice the size of the receiving antenna portion. Thus, the size of each antenna portion depends on the wave length of the radio wave for use. The intervals of the antenna elements are constant regardless of the wave length of the radio wave. In addition, with the same exciting weight, the beam pattern of the receiving antenna portion becomes the same as the beam pattern of the receiving antenna portion.

A signal received by an antenna element of the receiving antenna portion **1** is amplified by a reception signal amplifying portion **3**. The amplified signal is weighted by a weight setting portion **5**. The resultant signal is supplied to a receiving portion **8**. A signal that is output from a transmitting portion **9** is distributed and then weighted by a weight setting portion **6**. The weighted signal is amplified by a transmission signal amplifying portion **4**. The amplified signal is sent to the transmitting antenna portion **2**. The receiving portion **8** converts the received RF signal into a base band signal. The transmitting portion **9** converts a modulated base band signal into an RF signal. A signal processing portion **10** modulates/demodulates a base band signal. A controlling portion **11** controls signals to be sent to the outside and manages radio channels in association with the signal processing portion **10**. The controlling portion **11** detects the communication amount for each sector. The communication amount can be obtained corresponding to for example the number of terminals that are communicating for each sector and the number of channels in operation.

An antenna controlling portion **7** determines an optimum exciting weight of each antenna element corresponding to information of the communication amount for each sector received from the controlling portion **11** and sends the obtained exciting weight to both a reception signal weight setting portion **5** and a transmission signal weight setting portion **6**. At this point, the same exciting weight is set to the reception signal weight setting portion **5** and the transmission signal weight setting portion **6**.

FIG. 2 is a schematic diagram showing the structure of the weight setting portion and the amplifying portion of the receiving antenna portion.

Referring to FIG. 2, six sector beams are formed with 12 antenna elements **21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31,** and **23**. A low noise amplifier (LNA) **41** and a distributing units **42** are connected to each of the antenna elements. The distribution number n of the distributing units **42** represents that one antenna element is used to form n sector beams. The reception signal amplifying portion **3** is composed of the low noise amplifier **41** and the distributing units **42**. The weight setting portion **5** has beam forming circuits (BFN) **46, 47, 48, 49, 50,** and **51** corresponding to respective sectors. Each BFN sets up exciting weights for seven (or eight) antenna elements. The weighted signals are combined for each sector by a combining unit **45**. The combined signal is output to the receiving portion **8**. Amplitude weights are set up by variable attenuators **43**. Phase weights are set up by variable phase shifters **44**.

As with the receiving antenna portion, the structure for controlling the exciting weights is also provided to the transmitting antenna portion. However, in the transmitting antenna portion, high power amplifiers (HPA) are used instead of the low noise amplifiers. The positions of the distributing unit and the combining unit of the receiving antenna portion are reversed in the transmitting antenna portion.

FIG. 3 is a top view showing the antenna. Referring to FIG. 3, 12 antenna elements are disposed at respective vertexes of a dodecagon. FIG. 4 is an external view showing an antenna element **21**. Referring to FIG. 4, the antenna element **21** is composed of a plurality of planer antenna members **60** that are arranged in the vertical direction on a dielectric substrate **61**. However, when it is not necessary to form a beam in the elevation direction, the antenna element may be composed of a single antenna member. It should be noted that a microstrip antenna or a dipole with a reflector can be used instead of the planer antenna members. In this example, as a feeding method, a series feeding method or a tournament feeding method using microstrip lines can be used.

The features of the adaptive antenna according to the present invention are the controlling portion **11** as a means for detecting the communication amount for each beam and the antenna controlling portion **7** as a controlling means for controlling each beam pattern corresponding to the information of the detected communication amount. In particular, since the exciting weight of each antenna element is controlled corresponding to the detected communication amount and thereby the pattern of each beam is controlled, the deviation of the communication amounts of beams can be flexibly compensated. Thus, the communication capacity of the base station can be effectively used. In addition, the number of terminals that can be accommodated to the base station can be increased. Consequently, the cost can be equivalently decreased.

Furthermore, the shape of the transmitting antenna portion is analogous to the shape of the receiving antenna portion. In addition, the ratio of the size of the transmitting antenna portion to the size of the receiving antenna portion is equal to the reciprocal of the ratio of the transmission frequency to the reception frequency. Thus, when the same exciting weight is set to the transmitting antenna portion and

the receiving antenna portion, the shape of a sector beam of the transmitting antenna portion becomes the same as the shape of a sector beam of the receiving antenna portion. Thus, the shape of the transmitting sector beam becomes the same as the shape of the receiving sector beam. Thus, a communication defect due to the difference between a sector beam of the transmitting antenna portion and a sector beam of the receiving antenna portion can be prevented.

FIG. 5 is a flow chart showing a process of the antenna controlling portion 7.

The antenna controlling portion 7 determines the beam direction and the beam width of each sector so that the communication amount of each beam is equalized corresponding to the information of the communication amount for each beam received from the controlling portion 11. The antenna controlling portion 7 obtains exciting weights for forming such beams and outputs the exciting weights to the weight setting portions 5 and 6.

Next, an example of the process of the antenna controlling portion 7 will be described.

It is assumed that the beam width of each sector beam is switched in five levels that are 30 degrees, 45 degrees, 60 degrees, 75 degrees, and 90 degrees. In addition, it is assumed that the beam width as the initial value (nominal value) is 60 degrees.

First of all, the antenna controlling portion 7 inputs information of the communication amount for each sector from the controlling portion 11 (at step S1). The antenna controlling portion 7 obtains the average of the communication amount per unit time for each sector and determines the most crowded sector and the most uncrowded sector.

Next, the antenna controlling portion 7 determines a desired pattern (beam direction and beam width) of each sector beam corresponding to the following rules (at step S2).

Rule 1: The beam width of a sector whose communication amount is the largest (most crowed) is narrowed by one level (for example, the beam width is switched from 60 degrees to 45 degrees).

Rule 2: The beam width of the sector whose communication amount is the smallest (most uncrowded) is widened by one level (for example, the beam width is switched from 60 degrees to 75 degrees).

Rule 3: While the beam widths of the other beams are fixed, only the beam direction of the relevant beams are adjusted.

Thereafter, the antenna controlling portion 7 obtains the antenna exciting weight for the desired pattern of each sector beam (at step S3). The antenna controlling portion 7 outputs a weight control signal for setting the obtained exciting weight to the weight setting portions 5 and 6 (at step S4).

As examples of obtaining an exciting weight, there are several methods. As a first method, an optimum pattern is selected from several patterns that have been prepared. As a second method, an exciting weight is converged by, for example, a method of steepest descent so that a mean square error with a desired pattern becomes minimum.

Step S2 to step S4 are repeated until the difference between the communication traffic amounts of sectors becomes a predetermined value or less or until the beam width of a particular sector of which communications concentrates cannot be narrowed.

FIG. 6 shows an arrangement of patterns of sector beams in the case that the beam widths thereof are 60 degrees. When users concentrate in the +X direction and thereby the communication amount thereof increases, patterns are varied as shown in FIG. 7. The beam widths of sector beams (beams 1, 2, and 6) of which the communication amounts increase become narrow. On the other hand, the beam widths of sector beams (beams 3, 4, and 5) of which the communication amounts are relatively small become wide. In addition, the beam directions of individual sectors generally deviate in the +X direction. Such patterns are effective in the case that a place where people gather (for example, a station, an office district, an event hall, or the like) is present in a single direction viewed from the base station.

FIG. 8 shows an arrangement of patterns in the case that the users gather in both the +X direction and −X direction. The beam widths of the sectors in the +X direction and −X direction become narrow. In contrast, the beam widths of the other sectors become wide. Such patterns are effective in the case that the base station is disposed in the middle of a main road having heavy traffic. FIG. 9 shows patterns in the case that users gather in the direction of X>0. Such patterns are effective in the case that the base station is disposed near seashore or a mountain region and thereby the distribution of the users is geographically unstable.

As described above, with the adaptive antenna according to the present invention, the distribution of the users in the area that the base station covers can be compensated. With the adaptive antenna according to the present invention, the communication amounts of beams that are unbalanced due to the influences of geographical and traffic conditions can be compensated. In addition, the communication amounts of beams that are unbalanced due to temporal fluctuations can be compensated. When a sector beam of which communications are crowded is sharpened, the antenna gain of the area that the sector covers is increased. Thus, the transmission output power can be reduced for the increase of the gain.

Because of the above-described reasons, the adaptive antenna according to the present invention can very flexibly handle the variation of the communication state in the service area that the base station covers. Thus, it can be said that the adaptive antenna has very high use efficiency. For example, the adaptive antenna according to the present invention can equivalently increase the number of users (terminals) that can be accommodated several times as many as the conventional antenna has.

The present invention is not limited to the above-described embodiment. In other words, the present invention has other embodiments.

As another embodiment of the present invention, the patterns of individual beams are controlled in such a manner that the amount of the decrease of beam widths of the sector beams that are narrowed becomes equal to the amount of the increase of the beam widths of the sector beams that are widened. Thus, the total of the beam widths of all the beams is kept constant. The angular area covered with all sector beams can be more stably covered. Alternatively, the beam patterns may be controlled in such a manner that the amount of the decrease of the beam widths of sector beams that are narrowed becomes smaller than the amount of the increase of sector beams that are widened in as long as the difference of each value is smaller than a predetermined threshold value.

When beam patterns other than a beam with the largest communication amount and a beam with the smallest communication amount are controlled, it is preferably to fix the beam widths and vary only the beam directions. Thus, the beam patterns that cover one service area can be effectively maintained.